

Maturity Response of Ratoon Cane (*Saccharium officinarum* L.) as Affected by Pre-Harvest Cultural Practices in the Tropical Area of Ethiopia

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Abstract

To attain maximum sucrose accumulation, optimum maturity recommendation was needed depending on the soil type, cultivar type and environmental factors. To this end, an experiment was conducted to determine maturity response of ratoon cane (*Saccharium officinarum* L.) as affected by pre-harvest cultural practices. The sugarcane variety B52-298 was used as a test crop. The two experimental factors were four drying off periods (25, 45, 65 and 85 days) and four harvest ages (360, 390, 420 and 450 days) and their factorial combination was tested using randomized complete block design with three replications. Analysis of variance (ANOVA) showed that Drying off period significantly influenced maturity testing factors ($P < 0.001$). Hand refractometer brix% of all stalk parts, were significantly increased when the level of drying off period was increased with a peak at 65 days. In contrast, soil moisture content, sheath moisture content, were reduced with increasing drying off period. Effect of harvest age also significantly influenced the sheath moisture content and hand refractometer brix ($P < 0.001$). Increase in harvest age, significantly increased hand refractometer brix% of all stalk parts. Adjusting the drying off period to 65 days and harvest age to 450 days for variety B52-298 under the tested soil condition for ratoon crop is recommended as best maturity with optimum sucrose accumulation and is recommend for harvest.

Keywords: Maturity; Drying off period; Harvest age; Ratoon cane

Introduction

Irrigated sugarcane is dried off to prepare the field for harvesting and to enhance sucrose to be deposited preferentially in sugarcane stalks [1]. In sugarcane industry a crop should be dried off for the time it would take evapo-transpiration to equal twice the available soil moisture content of the soil in which the crop is rooted [2]. However, severe stress could develop in crops grown in low moisture available soils when completely suspending irrigation for a long period of time before harvest [3]. The days required for pre-harvest drying-off to improve sucrose accumulation in sugarcane could range from 30 to 150 days depending on low to high water holding capacity of the soil [4]. However, the optimum recommendations for drying-off management in Australia are 20-30 and 55-70 days for low and high water holding capacity soils, respectively.

Changes in sheath moisture content can well reflect the effects of water stress on plants [5]. Sheath moisture content is measured to determine the level of water stress as influenced by drying off period. As a result, after 35 days of drying off period the morphology was changed because sugar cane sheaths showed signs of wilting and dramatically decreased its moisture content [4]. Sheath moisture content was high in unstressed treatments but after 19 days after irrigation with held it was reduced from 80 to 75% [6]. The standard sheath moisture of sugarcane to have peak sucrose concentration was 68-74% [7,8].

The relative sensitivity of expansive growth to water stress compared with photosynthesis means that sucrose is diverted from growth to storage in bottom, middle and top stem parts. This phenomenon is exploited by the practice of 'drying-off' before harvest [9]. In 61% of the drying-off treatments in South Africa, there was a significant increase in the soluble solids together with dehydration throughout the stalk. However, sucrose yields only increase if water stress reduces stalk biomass by less than 4% or unchanged [2].

On the other hand, harvest age was one of the factors that determine

maturity of sugarcane. Sheath moisture content was reduced as harvest age increased because at later ages of growth there was a possibility that the crop may lost its potential of green leaves and root activities due to senescence. At a later age old root system of cane stalk gradually ceases to function and decay with time resulting to decreased sheath moisture content of the plant [8]. High sheath weight per stalk in young canes may be used as an indicator of the water status of the crop [10]. The percentage of sheath moisture content of sugarcane in old cane could be decreased because at senescence green leaves are dried and decrease in number [11].

In Ethiopian Sugar Estates usually cane maturity is customarily determined by taking the crop age and appearance as criteria for several years. From Scientific point of view chronological age of sugarcane is not a reliable guide to determine cane maturity alone [12]. Therefore, other factors such as varieties, weather conditions, and soil type may have more direct bearing on the real maturity of canes than the crop age [13]. The current sugar production of the Ethiopian Sugar Industry covers only 60% of the annual demand for domestic Consumption while the deficient is imported from abroad. In order to make the country self-sufficient in sugar and export the surplus sugar and produce ethanol and other by-products, the Federal government of Ethiopia is working

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DP (days)	HA (months)	SMC (%)	SHMC (%)	BRB (%)	MRB (%)	TRB (%)	ERS
25	12	38.26a ± 1.80	78.89a ± 2.43	11.10f ± 0.11	10.85g ± 0.13	7.56i ± 0.17	10.45i ± 0.08
	13	39.03a ± 2.93	76.16ab ± 1.99	11.28f ± 0.27	11.01g ± 0.42	7.85hi ± 0.47	10.78hi ± 0.64
	14	39.07a ± 2.26	71.55bc ± 3.98	14.03e ± 0.73	13.73ef ± 0.56	12.58g ± 0.60	11.43gh ± 0.39
	15	38.70a ± 3.91	75.54ab ± 1.11	15.94d ± 0.62	15.42de ± 0.48	15.44de ± 0.36	11.83fg ± 0.54
45	12	32.80b ± 0.89	77.46a ± 5.70	11.84f ± 1.09	11.68g ± 1.07	8.82hi ± 0.92	11.88fg ± 0.09
	13	32.54b ± 1.99	75.83ab ± 4.22	12.57ef ± 1.36	12.473fg ± 1.10	9.30h ± 1.13	12.38df ± 0.66
	14	29.82bc ± 3.39	74.38ab ± 5.25	15.99d ± 0.11	15.62d ± 0.37	13.18fg ± 1.56	12.97de ± 0.49
	15	30.72b ± 3.33	68.59cd ± 3.47	17.14d ± 1.59	16.96d ± 1.72	15.01de ± 0.20	13.05de ± 0.15
65	12	25.59cde ± 2.40	68.50cd ± 2.78	16.23d ± 1.08	15.70d ± 1.27	15.52de ± 1.16	13.50d ± 0.93
	13	23.880def ± 3.55	68.53cd ± 3.35	16.67d ± 1.56	16.11d ± 1.68	16.16d ± 1.58	13.70cd ± 0.93
	14	25.99cd ± 2.61	67.19cde ± 1.09	21.03bc ± 1.29	20.50bc ± 1.19	20.08bc ± 1.08	14.45bc ± 0.31
	15	24.31def ± 3.07	62.59ef ± 1.42	23.60a ± 1.08	23.37a ± 1.12	23.09a ± 1.13	15.42a ± 0.51
85	12	21.22ef ± 3.18	63.63def ± 1.49	15.80d ± 1.50	15.57d ± 1.50	13.36fg ± 1.48	12.28efg ± 0.51
	13	19.90fg ± 2.20	61.61ef ± 0.37	16.90d ± 0.46	16.67d ± 0.69	14.39ef ± 0.60	12.85de ± 0.41
	14	18.62g ± 2.21	60.95f ± 4.99	19.34c ± 0.16	18.94c ± 0.16	18.75c ± 0.12	13.12de ± 0.62
	15	18.58g ± 0.89	60.48 f ± 3.30	21.98ab ± 0.44	21.63b ± 0.45	21.49b ± 0.59	14.77ab ± 0.14
LSD		4.5	5.7	1.7	1.72	1.53	0.89
CV %		9.42	4.92	6.25	6.45	6.32	4.19

Table 1: DP, drying period; SMC; soil moisture content, SHMC, sheath moisture content; BRB, bottom refractometer brix; MRB, middle refractometer brix; TRB, top refractometer brix and ERS, estimated Recoverable sucrose given as mean ± SD. Numbers with in the same column with different letter(s) are significantly different from each other at p ≤ 0.05 according to LSD.

to establish sugarcane plantation on more than 400,000 ha in addition to the vast expansion project of the previously established farms with erection of high crashing capacity 10 new sugar mills.

Several maturity testing schemes have been proposed during the growing and harvest season. The common practice is to test the standing cane in the field for brix with a hand refractometer, which is a measure of the amount of sucrose in the cane [14]. Sugarcane matures when top/bottom brix ratio approached unity. It can also be done by using bottom minus top brix and bottom minus middle brix together and recommended to harvest when the two indices approach zeros [15]. The highest hand refractometer brix reading of top to bottom portion of ripened stalk is required to have 19 and 20% (a ratio of 0.95) brix %, respectively [16]. With stalk maturation, more and more internodes reach the same condition and a progressive increase in brix (total soluble solids to include sucrose) [17].

The importance of determining yield potentials for sugarcane has been noted by many scientists with goals to aim for barriers to be broken. Law of the minimum suggests that there is always some factor limiting yield. Therefore, yield potential need to be defined in terms of the limiting factor [18]. However, improper pre-harvest practices; drying off period (wet or excessive drying) of fields before harvest and harvesting many fields without optimum harvest age at field condition are common constraints in sugarcane production in Ethiopian Sugar Estates [19]. This will cause a decline both in yield and quality of sugarcane production due to high concentration of reducing sugars, and remobilization of accumulated sucrose to supply the continues growth of sugarcane plant. Over aged canes deteriorate their sucrose content by heavy lodging and remobilized to supply the unproductive bull shoots (newly growing shoots) [14]. Optimum maturity at field level considering drying off period and harvest age was not determined yet in sugarcane plantations of Ethiopia. Assuming this drawback, the study was carried out with the objective to determine effect of drying off period and harvest age on maturity of ratoon cane at field condition.

Material and Methods

The study was conducted on clay soils of Metahara Sugar Factory.

The clay soils cover more than 90% of the estate and they are grouped into four distinct textural groups as heavy clay, clay, clay loam and loam soil groups [20]. The experiment has two factors namely, drying off period (25, 45, 65 and 85 days before harvest) and harvesting age (360, 390, 420 and 450 days) with a factorial combination giving 16 treatments. Optimum drying off period and harvest age of ratoon.

Crops were not yet studied at Ethiopia Sugar Industries. To alleviate this problem the major sugar cane variety B52-298, was selected because of its high yielding potential. It covers 23% of the total area and it has first position out of the 13 commercial varieties in Metahara Sugar Estate.

The experiment was carried out on a first ratoon cane taking sample plots from the existing plantation of the commercial field using randomized complete block design (RCBD) with three replications in the cool season. Each plot had five rows with 10 m length and 1.45 m width for each row (10 m × 1.45 m × 5 rows) having an area of 72.5 m² for a single plot. The distance between plots was 2.9 m while it was 4.35 m between replications. The harvested plot consisted of three rows with 10 m length and 1.45 m width each (10 m × 1.45 m × 3 rows) with an area of 43.5 m².

Cultural practices such as weeding, fertilizer application, molding, pesticide application and irrigation frequency of the experimental field were based on the current practice practices of Metahara Sugar Estate except manipulating harvest age and drying off period before harvest.

Result and Discussions

Analysis of ANOVA revealed that drying off period significantly (p < 0.001) affected soil moisture content (Table 1). However, soil moisture content was not-significantly affected by different harvest ages. Soil sample was taken from 0-60 cm which is the optimum root zone of sugarcane varieties in Ethiopia Sugar Estates. Highest soil moisture content was recorded on the shortest drying off period (25 days) with no-significant difference among the different levels of harvest age. An initial soil moisture content of 45.58% was recorded two days after irrigation at field capacity as a reference to compare with the moisture loss by drying off periods. Thus, a sharp decline of soil

moisture content was observed when drying off period was increased to 65 and 85 days. The soil moisture content of $24.31 \pm 3.07\%$ obtained from 65 days drying off period and 15 months harvest age could be considered as adequate for maximum sucrose accumulation (Table 1). High soil moisture content was obtained in treatments exposed to short drying off periods [3]. However, soil moisture was reduced with increasing days of drying off period. Thus, longer drying off period was needed as the water holding capacity of soils increase to improve sucrose accumulation in sugarcane stalks.

Sheath moisture content of ratoon cane was significantly influenced by drying off period ($p < 0.001$) and harvest age ($p < 0.01$) while the interaction effect was not significant (Table 1). Treatments with 25 and 45 days drying off periods in combination with 12 months harvest age had the highest mean percentage of sheath moisture content 78.89 ± 2.43 and 77.46 ± 5.70 , respectively. The sheath moisture contents of were significantly reduced with increasing drying off period and harvest age due to water stress. Sheath moisture content was reduced with increasing levels of drying off period and harvest age in which enhancing water stress in the photosynthesis area of the plant [4,8]. This might be due to old root system of cane stalk gradually ceases to function and decay with time, an increased rate of leaf senescence, and a fairly rapid reduction in the number of green leaves per stalk. A depression in the leaf water potential could be an indicator of the dehydrative effect of water stress due to excessive evapo-transpiration [21].

Drying off period ($p < 0.001$) and harvest age ($p < 0.01$) significantly influenced hand refractometer brix% test of sugarcane parts but not by their interaction (Table 1). The highest hand refractometer brix% was obtained on 65 days drying off period and 15 months harvest age in all the bottom, middle and top parts of the stalk with the average value of 23.60 ± 1.08 , 23.37 ± 1.12 and 23.09 ± 1.13 , respectively. In thus drying off period and harvest age, all the stalk parts accumulated peak soluble solids indicating the sign of maturity to harvest. The lowest hand refractometer brix% in all stalk parts was recorded on the shortest drying off period (25 days) and the two earlier harvest ages. In general, sequential accumulation of soluble solids was observed from the base to the top of the stalk on different parts of the stalk. High brix content was obtained from the moderately dried and optimum maturity than fully irrigated and early harvested treatments, in all parts of the stalk with sequential accumulation of soluble solid from bottom to the top part of the stalk [14,22]. Drying off period and harvest age enhances brix content of the cane segments with high brix content at the bottom followed by the middle and top segments or with nearly equal percentage of hand refractometer brix on its all stalk parts at maturity [11,17].

Percentage of estimated recoverable sucrose was significantly ($p < 0.001$) affected by drying off period and harvest age. The highest percent estimated recoverable sucrose (15.42 ± 0.51) were obtained at 65 days drying off period and 15 months harvest age and the lowest value (10.45 ± 0.08) were recorded at 25 days drying off period and earlier harvest age (12 months) (Table 1). The increase of the percentage of quality parameters until 65 days drying off period was due to the decrease of the proportion of reducing sugars resulting in an increase of sucrose content. Because biomass was stored preferentially as sucrose rather than being drawn into the production of reducing sugars or non-sucrose materials (fiber). Withholding irrigation water beyond 65 days resulted in a decline of the value of all the quality parameters. This might be due to the fact that the stored assimilates were remobilized to supply the damaged part of the plant during severe stress. Sugarcane researchers indicated that moderate water stress in cane tissue was recognized as

a means of cane ripening because it decreased vegetative growth and hasten the quality parameters during ripening period [1,4]. The greatest contribution to change in sucrose dry weight concentration with drying off is from an increase in the dry weight concentration of soluble solids and sucrose content [23]. Percent of estimated recoverable sucrose significantly increased as age of sugarcane increased [24]. However, in over aged ratoon cane, the sucrose content is reduced due to heavy lodging and remobilization to supply the unproductive bull shoots (newly growing shoots) [14].

Conclusions

Improper drying off period and improper harvest age are recurrent problems of pre-harvest cultural practices, which severely affect maturity of sugarcane. Sheath moisture content was reduced increasing level of drying off periods and harvest age. On the other hand, increasing drying off period and harvest age increased brix% of the different stalk parts and percent of estimated recoverable sucrose.

In general, optimum percent of soil moisture 24.31 ± 3.07 , sheath moisture 62.59 ± 1.42 , highest hand refractometer brix of bottom 23.60 ± 1.08 , middle 23.37 ± 1.12 , top 23.09 ± 1.13 parts of the plant and estimated recoverable sucrose 15.42 ± 0.51 were recorded in the combination of 65 days drying off period and 450 days harvest age. Therefore, 65 days drying off period and 450 days harvest age were recommended for optimum maturity of ratoon cane to produce high sugar yield supplying to the mill.

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